

## Article

# The Assessment of Ecological Livability for Agricultural, Pasture, Forestry, Residential, and Tourism Activities; Study Area: North of Iran

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**Abstract:** Ecological livability assessment is one of the effective strategies seeking an optimum balance between the processes of urban development and ecological ones to ensure sustainable and livable environments ultimately. Since this type of evaluation is functional and practical for managers and planners, ecological livability is studied from different aspects (ecological, physical-social, economic). With an emphasis on ecological-infrastructure potentials, the present paper studies the region's capabilities in four activities: agriculture, pasture, forestry, residential, and tourism in northern Iran. Firstly, in the methodology and based on GIS, ecological-infrastructure indicators were investigated in the study area (Tonekabon City). Secondly, the four activities evaluated the ecological-infrastructure indicators according to the Delphi and ANP methods. Then they were combined with the Overlay function to prioritize the ecological-infrastructure potential of Tonekabon City for the activities. Findings from the study show that topographic and land capability indicators impact various activities concerning Tonekabon City's characteristics. The results of the research for the four activities in Tonekabon indicate that 35% of lands have a high potential for agriculture and pasture, more than 70% for forestry, 35% for tourism activities, and more than 73% for settlement ones in the category 1 and 2 (suitable, moderately suitable). In addition, the most ecological infrastructure potential is for agricultural-pasture, residential, and tourism activities in the northern of Tonekabon and forestry ones for the southern part. However, the high potential and power are in other parts of Tonekabon, especially the central sections, to establish several activities that it is possible to improve livability in the light of sustainable development through the investment in activities.

**Keywords:** ecological livability; infrastructure; capability and potential of the region; multiple criteria decision making (MCDM); ANP method



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## 1. Introduction

The acceleration of urbanization is one of the prominent features that characterize human civilization over the past millennium [1]. The process of urbanization has contributed significantly to the investment in infrastructures [2], the expansion of consumer goods markets owing to the increase in urban residents' incomes [3], the development of the modern service industry and the promotion of industrial structures [4]. However, apart from all the significant achievements, its destructive effects should not be ignored because urbanization acts as a "double-edged sword" [5], leading to problems such as the extremely excessive use of natural sources and energy and the deterioration of the ecological environment [6,7].

Rapid urbanization and industrialization have led to excessive energy consumption, natural resource depletion, and serious environmental pollution, which has put intense pressure on the natural ecological environment [7,8]. In the present age, there is less balance

between urban networks and natural contexts, so the linked set of cities dominates the vulnerable ecological systems [9]. Accordingly, the ecological environment is in a fragile and critical situation in line with the rapid changes in development patterns and land uses [10], which poses a grave threat to national and regional ecological security and sustainable development of social-ecological systems [11,12]. It should be noted that an area's ecological environment is not only a guarantee for sustainable urbanization but also a basic need for residents, production, and life in both urban and rural settings [13–15]. Thus, the ignorance of ecological infrastructure and the imbalance between the natural and artificial environment creates a crisis in livability [16]. The ecological and environmental problems do not seem to be resolved easily; however, it is obvious that monitoring and assessing the status and change of ecology appear really essential in order to understand the complexity of the challenges and sustain ecological integrity [17,18]. In several studies, the assessment of environmental impact has been considered. The most important of these studies are: assessing the ecological effect on land use [19–21], evaluating the potential influences of ecology and economic change [22–24], and determining the effect of urbanization on ecological efficiency and interaction [25,26].

One of the considerable benefits of such an assessment is that it will make more efficient conservation planning possible through prioritizing threatened ecosystems and their related services according to their value and livability [27].

Ecological livability assessment is one of the viable alternatives to establish complete equivalence between urban development processes and ecological ones in order to carry a reliable guarantee for sustainable and livable environments. This type of assessment is useful because livability is seen as a multidimensional, complex, and general concept [28]. Livability represents the sustainability of the environment and also puts great emphasis on the interrelationship and the quality of adaptation between people and the environment [29]. In other words, the livability of urban regions is considered a way to reduce the ecological footprint, avoid pollution and conserve natural resources in cities and surrounding areas [28]. Therefore, assessing the ecological livability of areas is one of the effective measures that devise a win-win plan by considering the vulnerability of the ecosystem of areas. With the help of this sort of assessment, planners are given an excellent opportunity to make the most practical decisions about the ecosystems of each area and construct a diverse range of land-use and conservation scenarios more sustainably.

According to the abovementioned matters, it seems necessary to describe ecological livability. There is no single definition for the concepts of a livable city and urban ecological livability [30–32]. However, many scholars laid stress on the long life and the requirements for the development of citizens [33–39]. So, it can be said that human, his demands and survival are the heart of a livable city [11,40]. Various aspects arise from ecological livability, including the impact of natural, ecological, socio-economic, and regional-spatial environments on the life of individuals. Each of the aspects has been studied in different ways to recognize its specific role in promoting ecological livability [41–48]. In fact, ecological livability specifies how environmental sustainability and livability can be implemented [49,50]; hence, the construction of an ecologically livable city has become a significant issue in the rapid development of new urbanization [51] because ecological livability accentuates the significance of ecology in planning and constructing of a livable urban city [40]. Studies conducted to assess a city's ecological livability mainly have dealt with two aspects of the ecological city and livable city. The assessment of ecological livability in a variety of topics (natural, socio-economic, and regional-spatial) were paid attention to in these studies. Most of the researches presented the model and evaluation index system for ecological livability, emphasizing different aspects [40,42,52,53]. Another group of studies prioritized biological elements and ranked the studied cities and regions in terms of ecological livability. In these studies, the effective drivers and indicators for promoting ecological livability were recognized [27,49,51,54–56].

Nevertheless, an issue that has received less attention in ecological livability studies is the comprehension of the potentials and limitations of the regions with the purpose of

boosting livability in the sustainability framework. This is because that understanding the capabilities and limitations of regions is a win-win strategy between biological activities and ecological considerations, leading to sustainable livability, while inattention to the potentials and actual capacities and a lack of appropriate use of ecological-infrastructural potentials (EIPs) bring about the destruction of the environment, the reduction in biodiversity, the disturbance of regional ecosystem and the decrease in livability level. In this regard, this article intends to investigate the region's capabilities in four types of activities, including agriculture-pasture, forestry, settlement, and tourism in Tonekabon (one of the northern cities of Iran) by asserting EIPs.

Tonekabon is located in the northern part of Iran and in the neighborhood of the Caspian Sea. According to the latest statistics provided from the country's yearbook, the population of this city is 166,132 people, with an area of 1732/2 square kilometers (Statistics Center of Iran, 2020). In addition, it comprises four cities (Nashtarud, Khorramabad, Shiroud, and Tonekabon) located linearly near the coast of the Caspian Sea (Figure 1 shows the spatial position of Tonekabon City). The city has coastal, plains, forests, and mountainous areas, and this ecological diversity is because of its location in a specific geographical location. Accordingly, the privilege of such ecosystem variations can be a proper platform to open up job opportunities, make tourism investments and planning, and create a healthy, safe, suitable, and environmentally friendly environment. Unfortunately, the current trend in the region points out a swift land-use change in favor of illegal construction, the rise of land prices, as well as distribution of tourists and tourism services without regard to ecological requirements (such as the development of construction and tourism facilities on the banks and riverside without consideration for legal issues related to river and coastal area) and the lack of investment in the sustainable revenue sector. Thus, it is essential to gain appropriate recognition of the extent of capabilities and potential of the region in the mentioned activities because, on the one hand, it is possible to develop and preserve the region's ecology. On the other hand, sustainable regional development can be achieved by investing in activities.

Therefore, it seems necessary to investigate the ecological viability of Tonekabon City from several aspects: (1) Tonekabon City is considered one of the most important areas due to its natural, geological, cultural, and historical attractions. Therefore, investing in sustainable industries such as tourism can lead to the improvement in the livability of the residents; (2) This city has a suitable potential for development due to its location on the route of three provinces (Mazandaran, Gilan, and Qazvin). However, the management process in this city has not been able to lead to a development in the direction of urban sustainability and improving the quality of livability due to the lack of recognition of the potentials and potential facilities and the lack of proper planning; (3) Tonekabon, as a coastal city, has always been exposed to the most exploitation due to the presence of rich resources. During the last decade, the improper exploitation of these valuable resources has made most of the coastal areas face a critical and dangerous situation. As such, the pressures on them have exceeded their environmental tolerance capacity. Some of the most important reasons for putting pressure on these areas are population growth, excessive use of resources, pollution of coastal areas, development of activities incompatible with the environment, and lack of coordination between activities in the beach strip. Therefore, the above problems have faced a serious challenge to the livability of the residents of the coastal areas; (4) Tonekabon is considered one city that accepts immigrants in Iran. This city is considered one of Iran's immigrant cities in the last decade. In addition, the phenomenon of reverse migration has intensified in Tonekabon City in recent years. Since migration is considered one of the factors of population change, it has negative and positive long-term and short-term effects; it has changed the social, economic, physical, and environmental structure of Tonekabon City. In addition to the intensification of land-use change in recent years as one of the consequences of the phenomenon of migration, the following can be mentioned as some of the most important consequences: increase in the price of land and housing, cultural and social dualism, increase in crime, destruction of landscapes,

ecological instability, and indiscriminate construction. Therefore, the continuation of the above factors is a warning to reduce the livability of Tonekabon City.

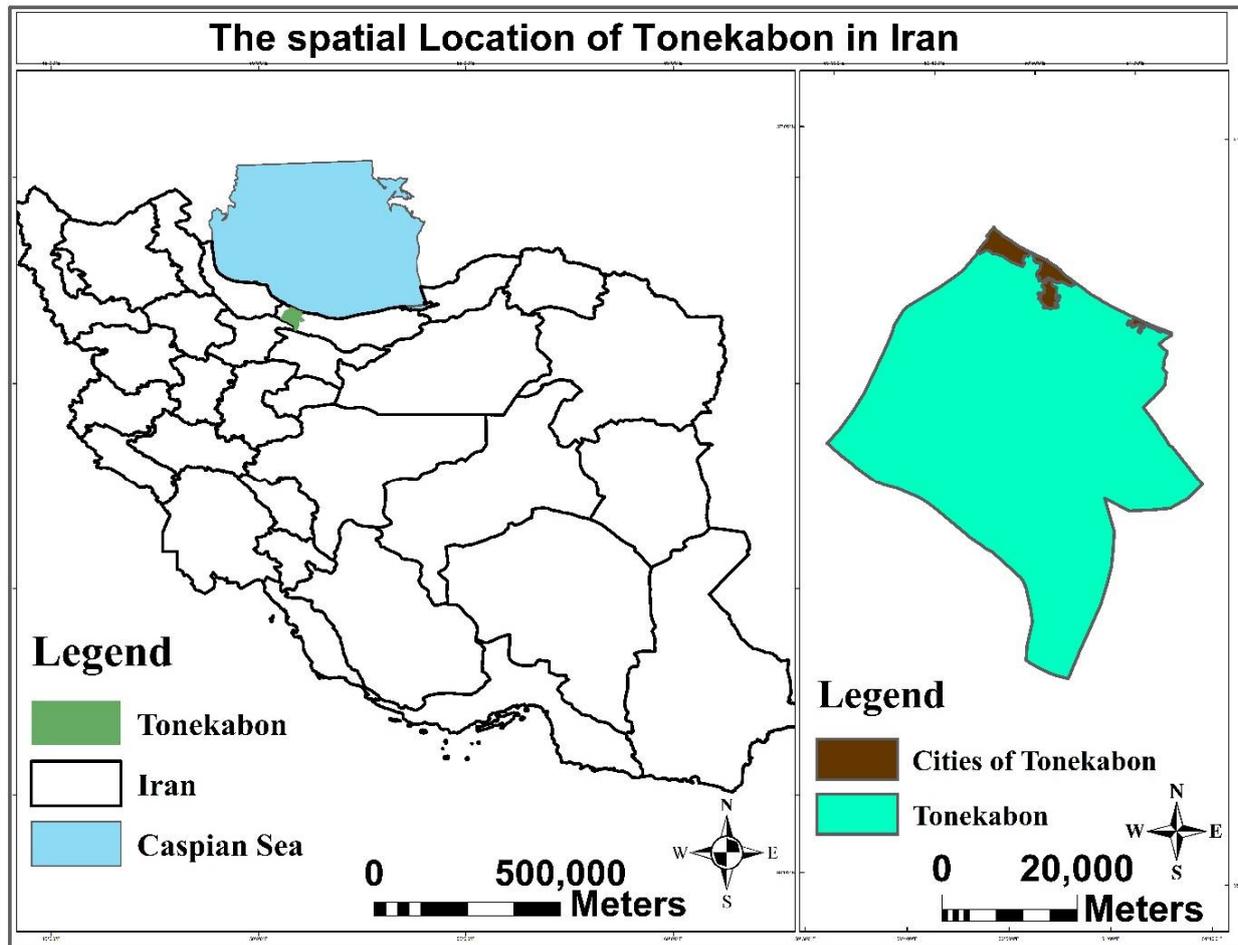


Figure 1. Location of Tonekabon (2022).

## 2. Methodology

The emphasis of the present study is on ecological livability indicators (Table 1). Therefore, the data were extracted from documentary sources, surveys, and spatial information. In fact, the documentary method of statistical yearbooks and the library research method were employed to collect views and experiences. The survey method contains observation and collected information that was stored in different data layers in the GIS database. Spatial information in the form of Vector, Raster, and Tin was assembled from organizations and sites. The data on land use and data related to Deme were extracted from the site of the Iran Mappin Organization, the data of electricity and gas lines were pulled out of the site of municipalities, and the data associated with roads were also obtained from OpenStreetMap. Then, spatial and non-spatial information was combined and analyzed after completing the database in GIS. In the next stage, the current situation of Tonekabon was evaluated and measured in ecological livability. It should be noted that in addition to using GIS analytical functions, including overlapping, buffering, etc., descriptive statistics in the shape of tables, geometric representations, and raster activities in the form of layer overlap analysis (index overlay) in ArcGIS Software were used in order to make a close analysis (Table 2). Moreover, the Analytic network process (ANP) was exerted for weighting, and the Delphi method (opinion of experts) was applied to weight the indicators. Therefore, the details of the research steps can be described as follows:

**Table 1.** Ecological livability indicators of research.

Explanations	Indicator	Resources
Topographic studies (slope, aspect, altitude) aim to assess and analyze surface roughness characteristics. Thus, the digital elevation model (DEM) is used to draw the slope and aspect map. Topographic attributes influence the growth of plant and tourism and sports activities such as mountaineering and skiing so that the amount of energy received by the surface, which has the same slope but the opposite geographic direction, is different in the amount of energy obtained through the sun on the southern domains versus the north ones. The southern and southwestern domains of the northern hemisphere receive more energy. From some scholars' viewpoints, the slope is one of the most significant factors in comprehending the spatial distribution of landslides.	Elevation  Slope and Aspect	[57–60]
Analysis of how different land uses are put together is crucial in urban planning since each land-use conflict with some land use and is compatible with others. Based on the compatibility matrix, land uses are in the following categories: (a) fully compatible, (b) relatively compatible, (c) medium (Indifferent), (d) relatively incompatible, (e) completely incompatible	Land-use compatibility	[61,62]
Land capability is the ability to accept a type and intensity of land use occurring under the observation of given management without long-term degradation for a permanent or specified period. Physical aspects, including hydrology, geology, and geomorphology, are essential in determining land capability. Therefore, it operates as a major tool for better land use	Land capability	[63,64]
Roads play a significant role in bringing economic benefits for comprehensive development. The roads are the main element of access facilitating public transportation, land management, resources, and traditional land uses	Accessibility to road	[65,66]
On the one hand, the construction of gas and electricity pipelines can have a great impact on ecological improvement, on the other hand, it can cause irreparable damage to the ecology of an area. Thus, the determination of the standard distance for the construction of gas pipelines and power lines should be considered because of the decline of ecological impacts and the acquisition of the desired results	Distance from power transmission lines Distance from gas transmission pipelines	[67]

The first step is the selection of effective factors in the assessment of ecological livability and the determination of the data matrix. Ecological livability indicators were determined by studying the research literature and characteristics of the studied area. The research indicators include topography (slope, aspect, altitude), land-use compatibility, land capability (hydrology, geomorphology), road accessibility, and distance from electricity transmission lines, distance from gas transmission lines).

The second step is to draw information layers (indices). After selecting the layers and sorting the data, the initial layers were drawn according to the explanation that the slope layer and elevation layers of the area were obtained by preparing the DEM map. The Raster Surface tool has been used to draw slope and aspect maps.

In order to draw the compatibility of land uses, the GIS-based layers were prepared with the shape file formats. Then, using Distance and Reclassify tools, standard distances were defined based on the degree of land-use compatibility with respect to the four activities.

After preparing the hydrological and geomorphological layers, the geometrical correction was performed to draw the land capability map. After preparing the layers, each indicator was classified. Therefore, according to the characteristics of each of the four activities, the classification of hydrological and geomorphological indicators was different (for example, the type of soil depth classification, which is one of the geomorphological indicators for agricultural activities, is sometimes different from residential activities if they are sometimes placed on the third floor for residential purposes). The next step was the integration of land capability layers. The Intersect tool was used to integrate the hydrology and geomorphology layers. After integration, the next step was grading for indicators. This is performed by applying limitations in Gis. Therefore, the Field Calculator tool was used to define the limit/no limit for land capability. Then, in the final stage, the land's capability was classified using the Select by Attributes tool. Therefore, the degree of land capability was drawn according to the nature of each of the four activities.

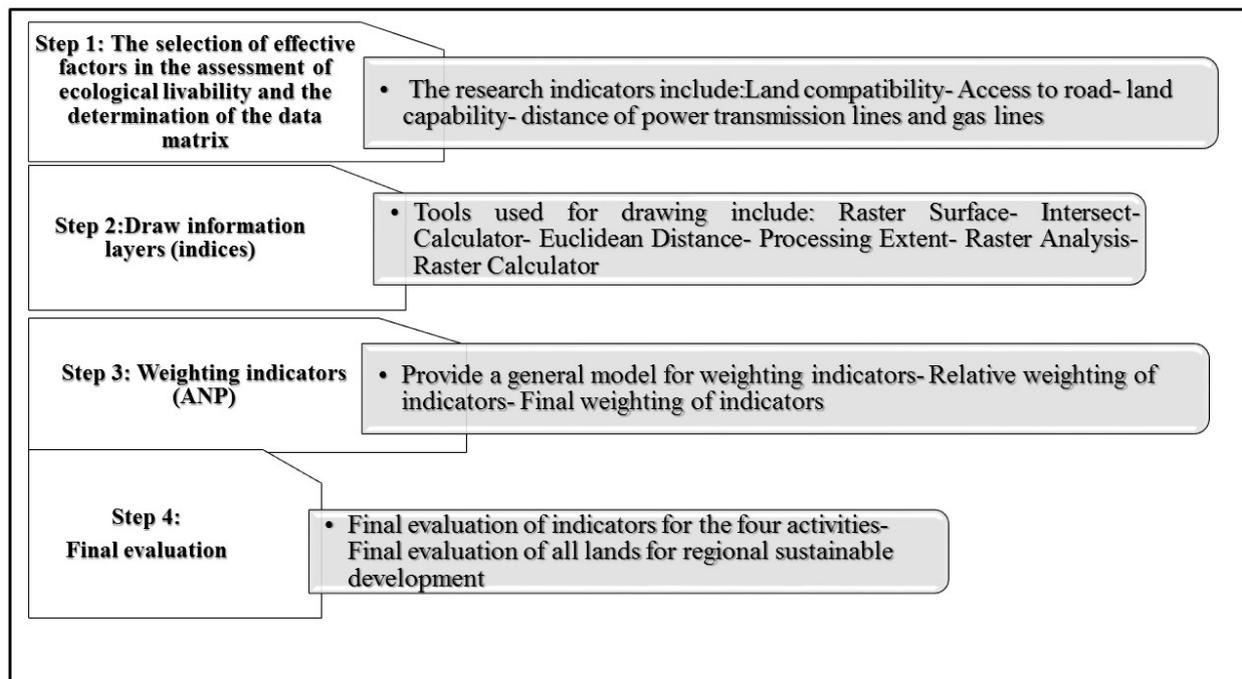
Euclidean Distance, Processing Extent, and Raster Analysis tools were used to draw maps of distance from communication ways and distance from gas and electricity lines. In this part, the standard intervals for each of the indicators were chosen according to the characteristics of the complications.

**Table 2.** Functions used in ArcGIS.

Functions	Explanation
Euclidean Distance	It is possible to establish a zone or distance from a layer's element using this function. This function is one of the most widely used neighborhood functions that was carried out in locating, zoning, and modeling.
Reclassify	The operation of classification and reclassification modifies descriptive data in a layer and classifies topics into a number of desired layers. The classification procedure allows the user to interpret data correctly and easily by grouping and putting data in these groups.
Raster Calculator (Map Algebra)	Raster Calculator called Map Algebra in Arc Gis environment is one of the available tools in ArcGIS that can combine different data (different layers of information generated from several sources and do not have the same unit and scale and have structural differences in geometry).
Weighted Overlay	Using the Weighted Overlay analytical function is one of the methods of analyzing spatial data in ArcGIS. It is utilized to interpolate the weighted layers in the ArcGIS environment to analyze multiple and heterogeneous inputs comprehensively.

The third step is to determine the weight of the indicators. Delphi method (opinion of experts) was used to weight the indicators. The statistical community of experts included specialists in the field of urban planning and experts in environment, ecology, ecotourism, and geography. In addition, 10 people were selected as the sample size by using targeted sampling. Finally, after obtaining the importance of each indicator, the combination of the obtained weights and the determination of priorities were discussed. It should be noted that the weight of each indicator for the four activities (due to the difference in functional nature) was calculated separately.

In order to determine the appropriate places for the development of activities (fourth step), the layers had to be classified first. How many layers each layer has, and which layers are the most important in each layer? Reclassify tool was used for this. In this section, each layer is valued according to the number of floors. Each class that has the most importance was given the highest number (for example, in the present study, the slope indicator has 10 classes). The lowest slope in each class (due to more suitable conditions for activities) was given a score of 10. Therefore, according to the functional nature of the four activities, the importance level of each of the classes has been different for the layers. The next step was to use the Raster Calculator tool to overlay and calculate the weight of the layers. Therefore, the weights obtained according to experts' opinion and with the ANP method were multiplied in the layers using this tool. In the next and final stage, the Symbology tool was used to classify and determine suitable places for the development of activities. It should be noted that all these processes were performed separately for the four activities. Therefore, the stages of research are briefly mentioned in Figure 2.



**Figure 2.** Steps of conducting research.

#### *The Analytic Network Process (ANP)*

The analytic network process (ANP) is one of the multicriteria decision-making techniques. This method was introduced by Thomas L. Saaty in 1996 and is a continuation of the AHP method. ANP has all the positive features of the Analytic Hierarchy Process (AHP), such as simplicity, flexibility, the use of quantitative and qualitative criteria simultaneously, the ability to check consistency and judgments, the analysis of complex relationships between elements, with the difference that this method does not assume that there is no relationship between different levels. The components in the hierarchical structure are made up of different rules that usually affect the low-level components on the higher-level components. In this situation, the system has a network structure from which the ANP model is derived. All elements in a network can communicate with each other. Therefore, ANP can be considered as consisting of two main parts: control hierarchy and network communication. Hierarchical control include the relationship between the goal, criteria, and sub-criteria, and it affects the internal communication of the system, and network communication includes the dependence between elements and clusters. The implementation of the ANP involves the following four main steps [68]:

Step 1: Transforming the problem into a network structure

Step 2: Pairwise comparison and determination of priority vectors

Step 3: Supermatrix formation and converting it into a limit supermatrix

Step 4: Prioritizing and selecting alternatives

ANP is unique in that it provides composite scores, which indicate the relative ranking of different options available to the decision maker. However, some of the disadvantages of the ANP method include identifying the problem-related features and determining their relative importance in the decision-making process, multiple pairwise comparison matrices formation, and spending a long time to perform calculations.

### **3. Research Findings**

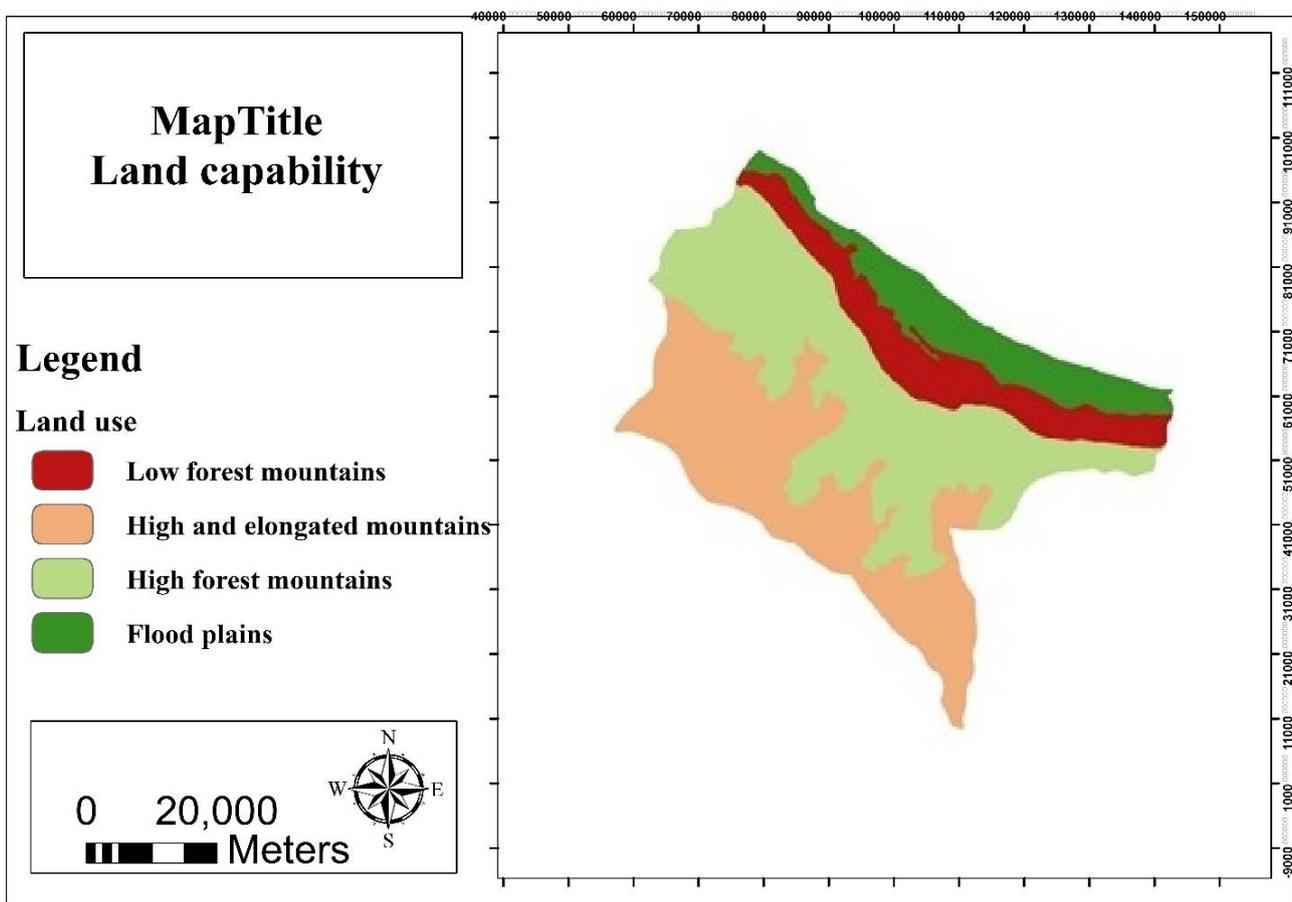
#### *3.1. Current Status of Land Capabilities*

Before scrutinizing the standing of ecological livability indicators in the four activities, first, the total land area of the study area must be calculated then the number of used levels should be determined for their land capability. This is because the capability of

urban land sources is the basis of human survival and social development that the rational utilization of lands signifies the need to attain the goals of sustainable urban development. In this regard, four classifications of major land uses are shown in Table 3 for Tonekabon. Therefore, according to the above, a map of land capability was drawn in order to be acquainted with how to use the land and designate the spatial location of each type of land use in the study area (Figure 3).

**Table 3.** Land capacity of Tonekabon City (2020).

Land Use	Area (Square Meters)
Flood plains	323,313,833
High and elongated forest mountains	890,761,431
High forested mountains	1,075,431,603
Low forest mountains	356,264,121
Sum	2,645,770,990



**Figure 3.** Current status of land capabilities.

### 3.2. Evaluation of Ecological Livability Indicators

Scientific and political debates about the principle of sustainable development have contributed to the usage of environmental protection and improvement to guide human activities and interventions [69]. In this respect, recognizing EIPs is important before loading various activities. Hence, assessing the indicators of ecological livability is the first step of the research process regarding spatial suitability requirements. Then, in the next steps, indicator layers (elevation, slope, land-use compatibility, land capability, accessibility

to roads, distance from power transmission lines, distance from gas transmission pipeline) are selected and prepared to assess the capability of the study area in four kinds of activities including agricultural-pasture, forestry, residential, and tourism.

### 3.2.1. Slope and Elevation

The elevation map was extracted with an accuracy of 10 m by using topographic maps of the region. A digital Elevation Model (DEM) is accurate to 10 m. Curved lines provide the topographic map of elevation fluctuations in the study area, but they can be detected more easily and quickly by preparing DEM. Figure 4 indicates the elevation fluctuations along with the consideration classes. Altitude represents the change of climatic fluctuations. The amount of energy each point of the earth receives from the sun is different due to the elevation difference. The percentage of humidity and precipitation changes as the pressure increases and the altitude decreases. Therefore, elevation changes can profoundly influence temperature, precipitation, and humidity parameters.

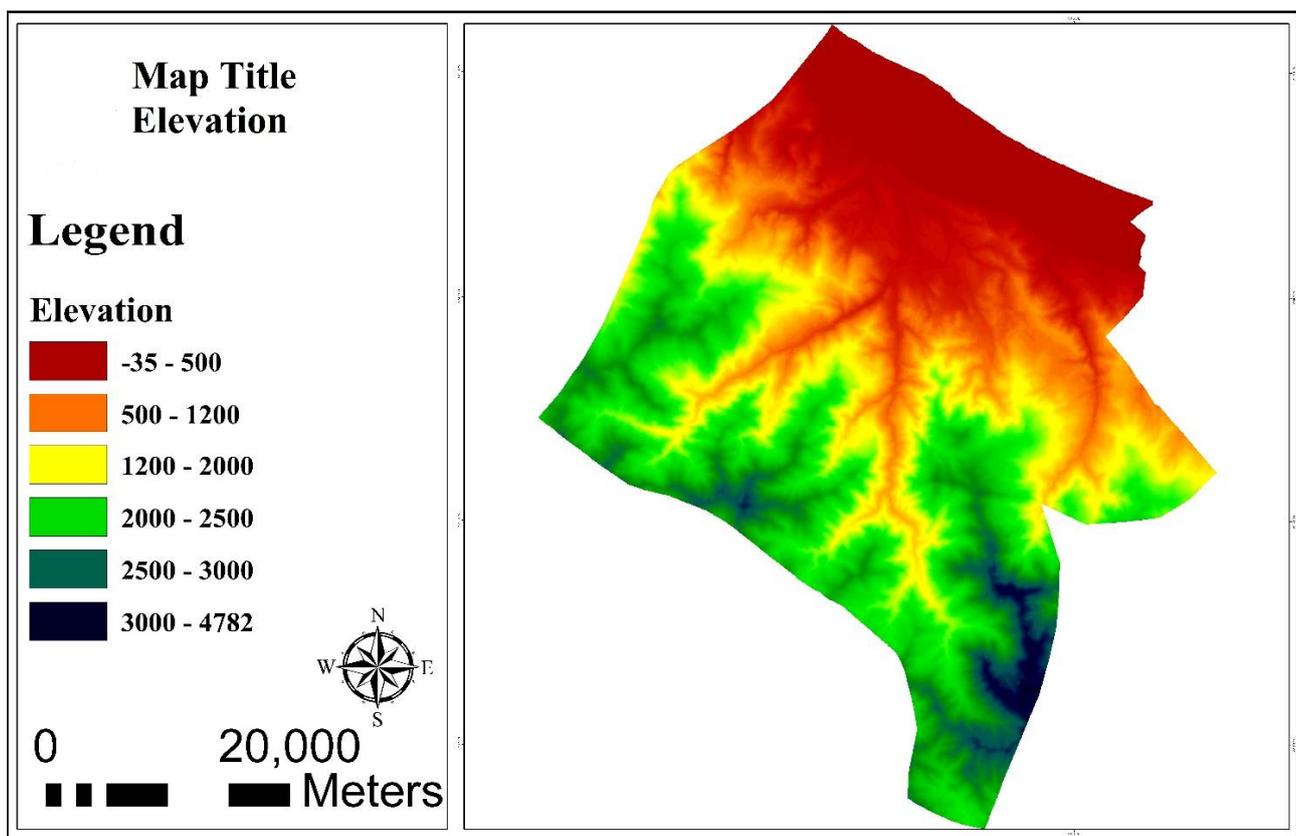


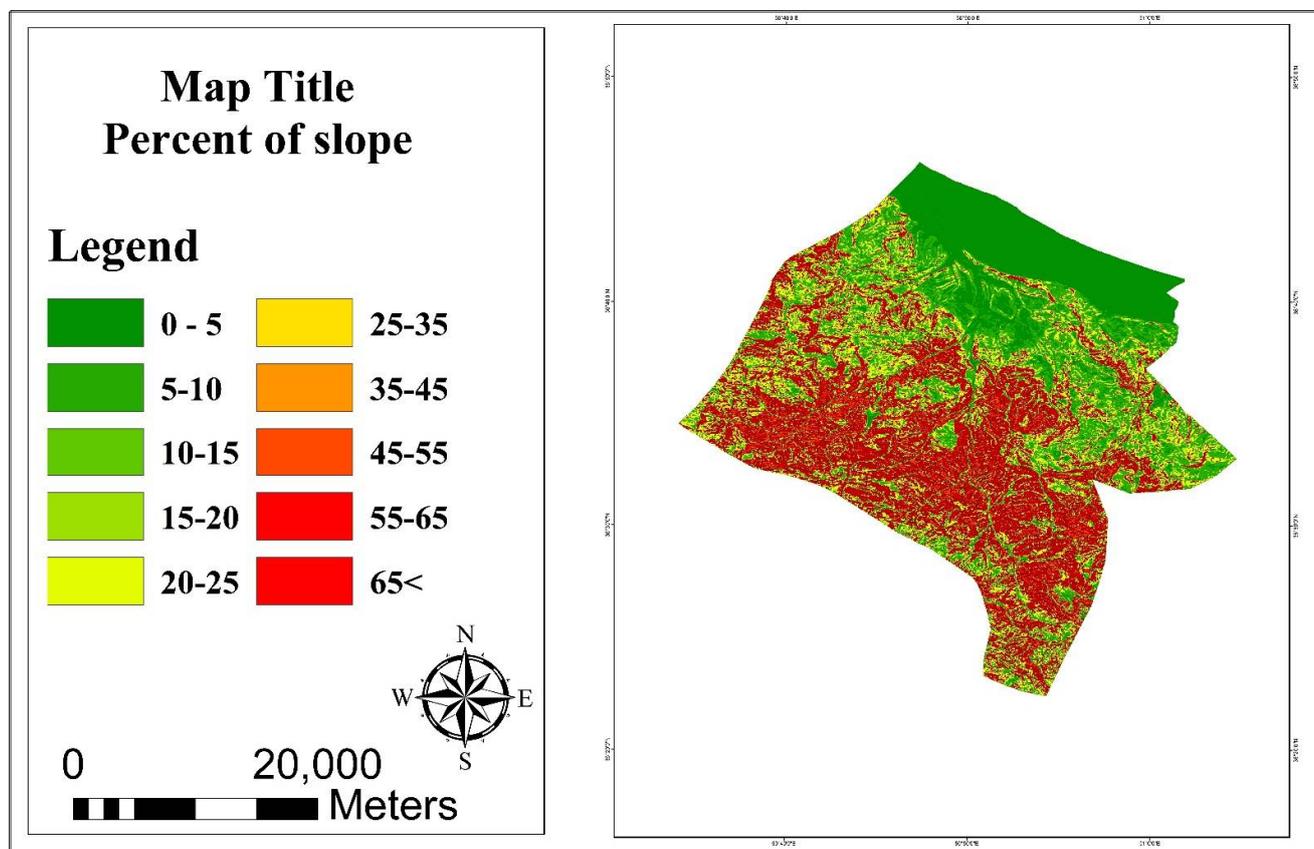
Figure 4. Elevation classification.

For topography, an altitude of 400 to 1200 m above sea level is suitable for urban development and residential activities, and more than 1800 m are unsuitable.

### 3.2.2. Slope

The area's slope and aspect were plotted using the Dem map and elevation classes (topography). Thus, the slope map was made in 10 groupings (Figure 5). In terms of urban development, the very suitable slope is less than 15% (lower than 10 degrees) [70,71], although up to 25% was also assessed as suitable [72,73]. Since urban morphology is more susceptible to natural hazards such as floods, the highest score is given to slopes with lower degrees. This is due to the fact that geological catastrophes and economic losses are the damaging consequence of increasing the slope by more than 25% so that this rate ascertains the topographic status of the type of development [70,74]. Hence, in the present study, less

than 15% slope can be suitable for agricultural and residential activities, and the higher slopes are ideal for forestry and tourism ones.



**Figure 5.** Slope classification.

Additionally, the map of the aspect is presented in Figure 6. As mentioned, the aspect produces a binding effect on the growth of plants and tourism and sports activities such as mountaineering and skiing, the amount of received sunlight, and the number of landslides [58–60].

### 3.2.3. Land Compatibility

It is strategically vital to arrange different land uses together as their improper arrangement can dwindle the level of livability and efficiency of the various land uses. Land compatibility is divided based on the absence of disturbance and hindrance in the implementation of each other's activities. The effective factors in compatibility and incompatibility of uses include noise pollution, air pollution, safety, comfort and convenience, land size and dimensions, visibility, and scenery. According to this, users may have the following modes in terms of compatibility [50]:

#### A. Fully compatible

It means that there is a common feature, and the activities of the users should match each other, such as two low-density housing.

#### B. Relatively compatible

In this group, users are of the same type but differ in details. Such as low-density housing with medium-density housing.

#### C. Medium compatible

Land uses are indifferent in terms of compatibility with each other.

D. Relatively incompatible

The degree of incompatibility between land uses greater than their compatibility.

E. Completely incompatible:

There is no match between user profiles, and they are in conflict with each other. Such as industrial land use and settlement land use.

In Figure 6, the results of land valuation are presented in terms of compatibility with land uses.

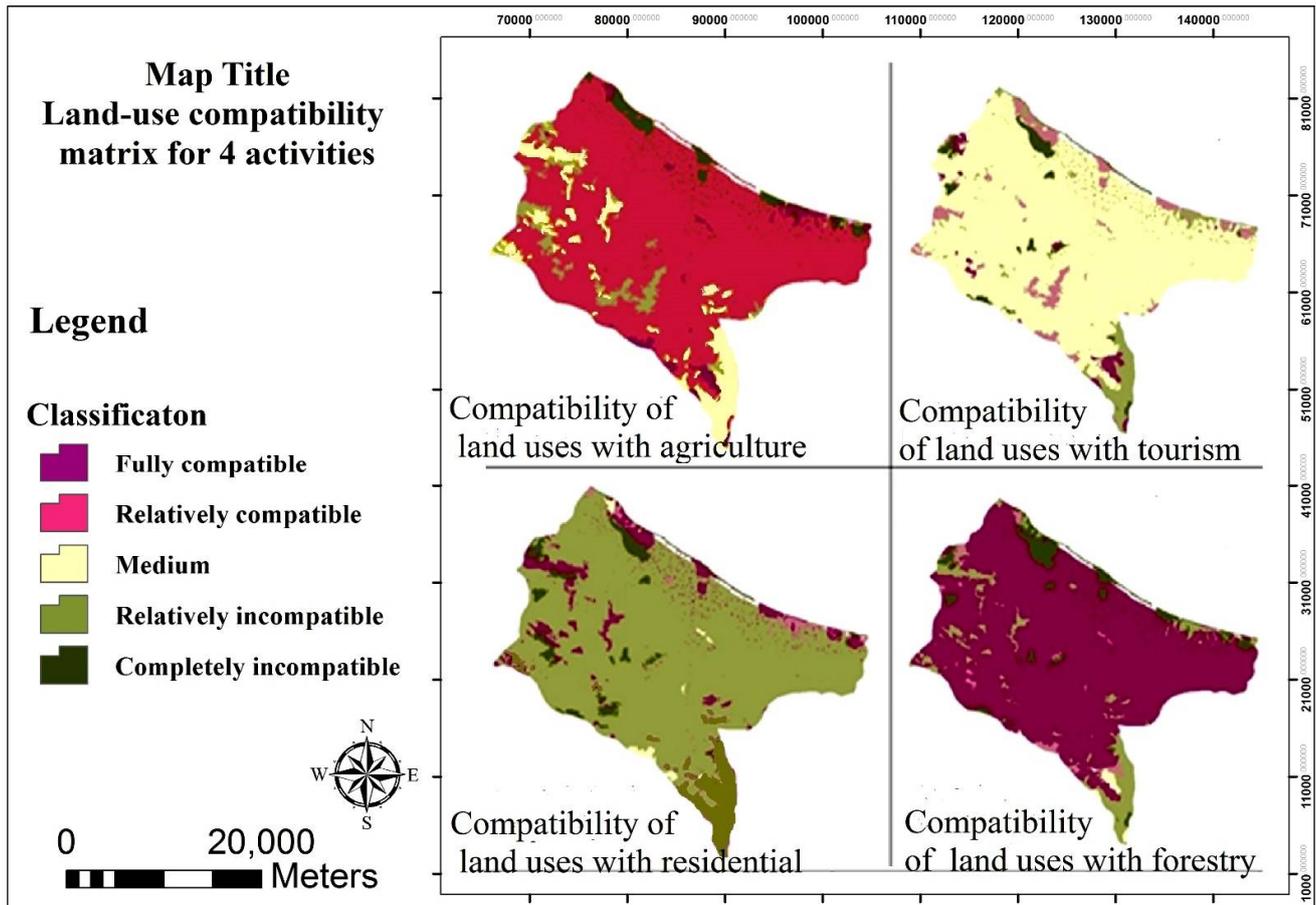


Figure 6. Land-use compatibility matrix for 4 activities.

### 3.2.4. Land Capability

In this study, the land capability is a sign of the inherent ability of land following characteristics, for instance, hydrology, geomorphology, and geology. Since topographic features were separately considered indicators, the land capability was removed from the information layer.

As noted, there are four types of capabilities for status quo lands. Land capabilities encompass flood plains, high and elongated forest mountains, high forest mountains, and low forest mountains. Figure 7 shows land valuation for four uses: agriculture, tourism, forestry, and settlement. The prioritization with reference to the nature of activities was quite a crucial point that was observed in the assessment of land potential, more precisely, flood plains for settlement, forested mountains for tourism, low-lying areas for agriculture, high and elongated forest mountains for forestry were in the first rank.

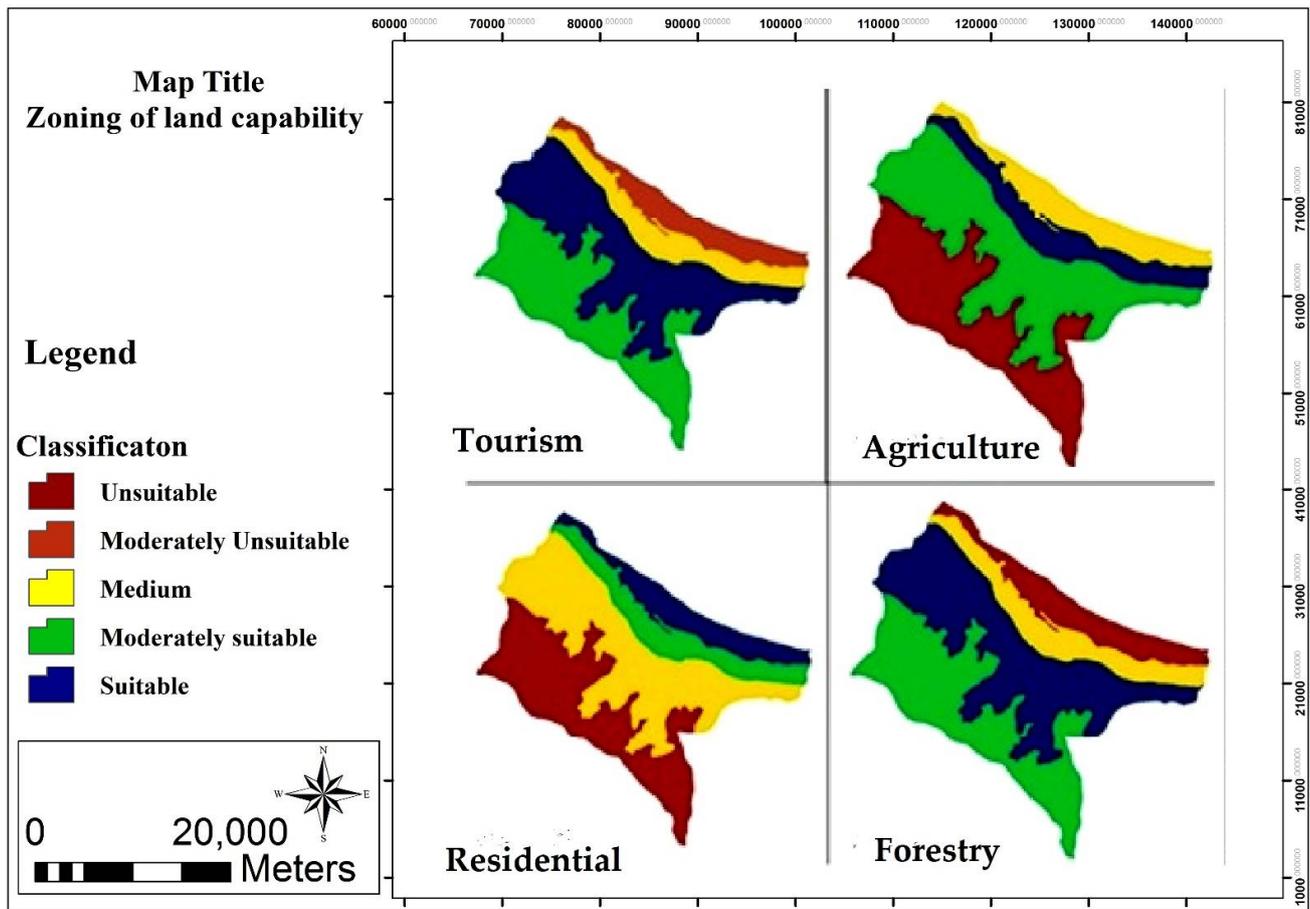


Figure 7. Zoning of land capability elements for the development of 4 activities.

The forestry potential of Tonekabon lands enjoys a smaller area in the urban domain than other land-use capabilities despite the wide expansion of forests outside the projected area. In discussing the potential of forest lands, the preservation of existing forests is one of the prime targets for a planner before any criteria. The local ecosystem and plant species that have resisted and adapted to environmental and climatic conditions for many years will have high stability.

Furthermore, the natural forests own a cohesive ecosystem and a vital chain; if one of their elements is destroyed, ecological and environmental devastation will occur irreparably.

### 3.2.5. Roads

Roads play a constructive role in bringing economic advantages for inclusive development; however, they contribute to deforestation and other adverse environmental effects. Therefore, the evaluation and classification of roads for forest activity are different from other activities, including agriculture, tourism, and settlement [75]. Meanwhile, the type of a hierarchy and functional characteristics of roads are of outstanding importance for use.

**Functional characteristics of roads:** Urban roads have functions comprising mobility, accessibility, social performance, urban architecture, and climatic and economic effect that the function of accessibility is one of the main criteria of urban classification (According to the report of the Iranian Organization of Municipalities and Rural Affairs and National Standard Organization of Iran).

**Hierarchy of roads:** The hierarchy of roads consists of freeways, highways, major arterial roads, minor arterial roads, and local, collector, and distributor roads. Most of the roads for Tonekabon are in the category of collector, distributor, and local roads. Given this, impossible and dangerous roads have not been considered.

The suitable distance of the four types of land uses from roads is shown in Figure 8. Access to roads is vital for residential, tourism, and agricultural activities.

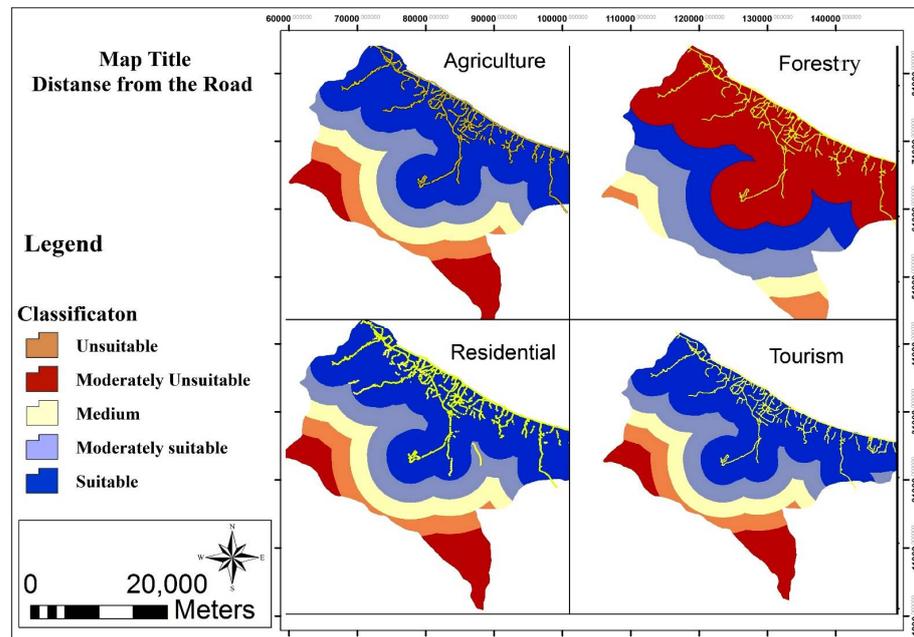


Figure 8. The status of the 4 activities in relation to access/inaccessibility to the roads.

### 3.2.6. Distance from Power Transmission Lines

The evaluation of activities in terms of distance from power lines is shown in five sorts: unsuitable, moderately unsuitable, medium, moderately suitable, and suitable. The optimal place for residential and tourism land uses close to power transmission lines, and for forestry and agriculture, one is the distance from these lines. Figures 9 and 10 show the distance of land uses from power lines.

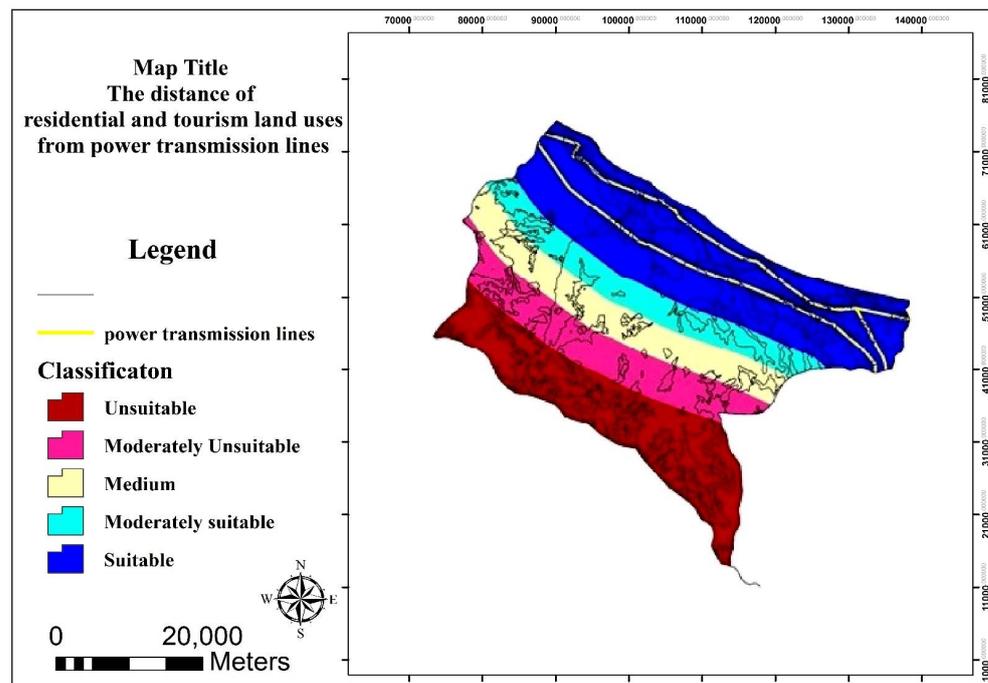


Figure 9. Residential and tourism land-use distance from power transmission lines.

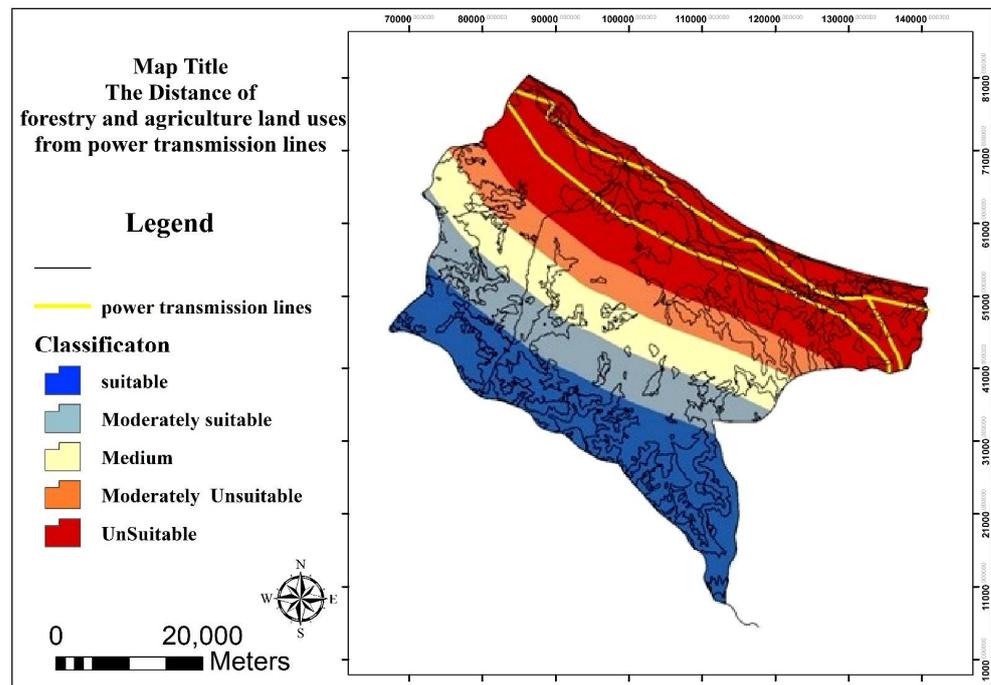


Figure 10. Distance of forestry and agriculture land uses from power transmission lines.

### 3.2.7. Distance from Gas Transmission Pipelines

It is necessary to consider the minimum distance from the gas transmission pipelines for tourism and residential activities; conversely, the farther the distance is, suitable it is for agriculture and forestry. The proper distance for residential and tourism, such as forestry and agriculture land use from the gas transmission pipelines, is shown in Figures 11 and 12, respectively.

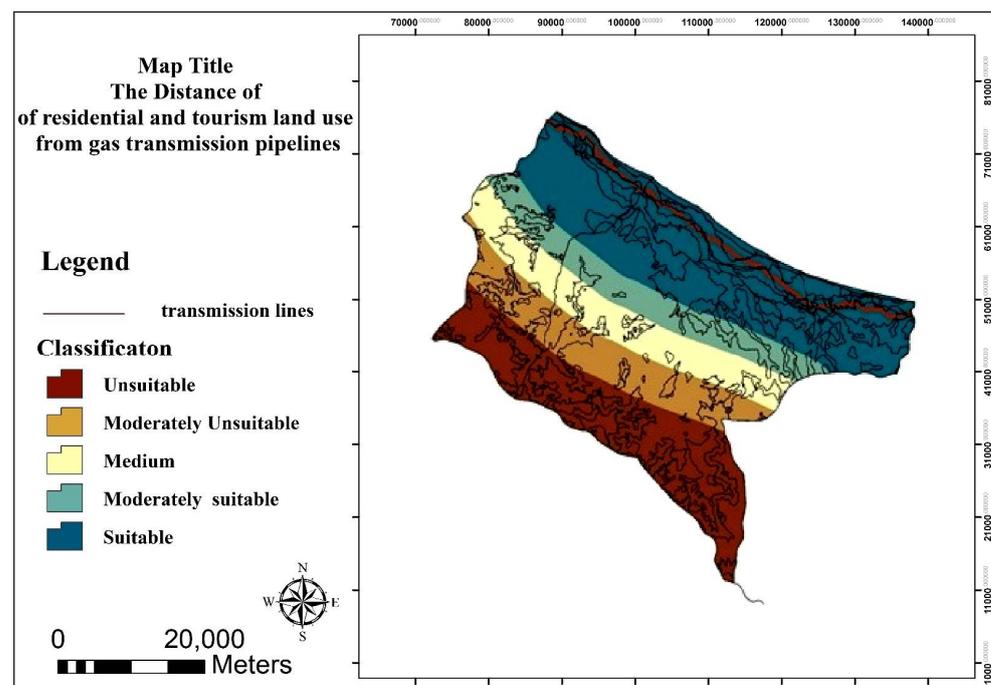


Figure 11. Distance of residential and tourism land use from gas transmission pipelines.

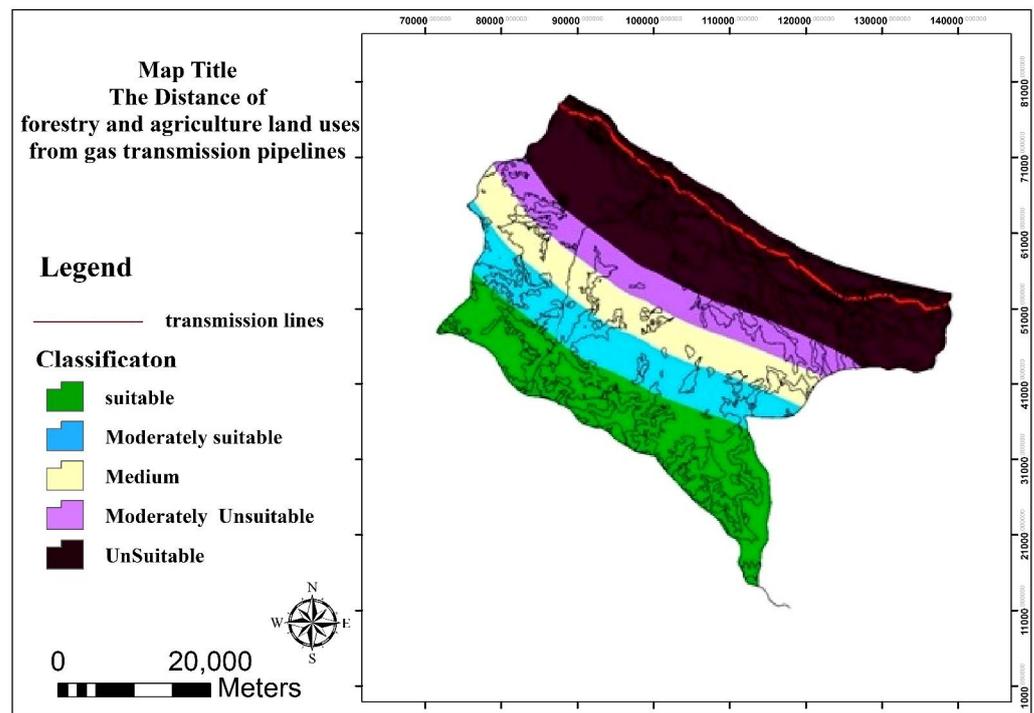


Figure 12. Distance of agriculture and forestry from gas transmission pipelines.

### 3.3. The Weighting of Ecological Livability Indicators

After the evaluation indicators have become comparable and standard scales, the relative weight and importance of each of them should be determined using expert opinions and in relation to the intended purpose. In this paper, the Analytic network process (ANP) was used to determine the relative weight of each specific index. ANP is a flexible method for the quantitative and qualitative study of multicriteria problems, and its distinctive feature is reliant on two-layer comparisons. The general model presented in the research is shown in Figure 13.

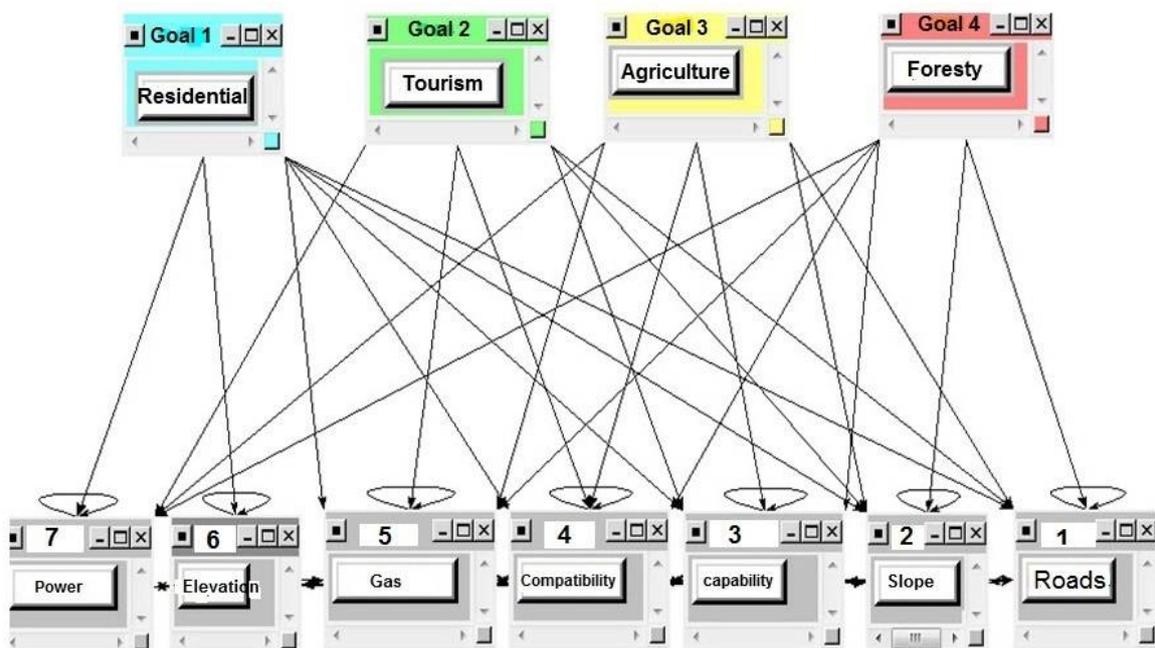


Figure 13. The general model for weighting indicators in analytic network process (ANP).

The weighting of the criteria in ANP is similar to the binary comparisons performed in AHP. In ANP, each component is given a weight according to its corresponding component, which is located on top of it. This weighting is given as reported by the experts' opinion regarding the relative importance of different components. The average opinion of experts was used because more than one expert was consulted in this regard. For this purpose, since the studied criteria had an interaction, they were first compared in pairs (Table 4). Then, in the next step, the final weight of the indicators was calculated (Table 5).

**Table 4.** The relative weight of locating criteria.

	Compatibility	Slope	Altitude	Access to Power	Access to Gas	Land Capability	Access to Road
Land compatibility	0.05	0.05	0.04	0.05	0.04	0.03	0.04
Slope	0.27	0.27	0.33	0.36	0.29	0.32	0.32
Altitude	0.22	0.22	0.21	0.20	0.23	0.23	0.22
Access to power	0.07	0.07	0.06	0.07	0.06	0.05	0.06
Access to gas	0.09	0.09	0.08	0.07	0.09	0.08	0.08
Land capability	0.17	0.17	0.16	0.13	0.18	0.15	0.14
Access to road	0.14	0.14	0.12	0.12	0.13	0.14	0.15

**Table 5.** Final weight of criteria location of uses.

	Residential	Tourism	Agricultural	Forestry
Land compatibility	0.04843	0.07430	0.113	0.27227
Slope	0.29232	0.25417	0.22278	0.10602
Altitude	0.18626	0.17122	0.2237	0.16942
Access to power	0.7697	0.8758	0.8129	0.4142
Access to gas	0.10242	0.11104	0.08713	0.04593
Land capability	0.13699	0.19632	0.14689	0.19662
Access to road	0.15661	0.10536	0.12522	0.16831

Finally, the combination of obtained weights and the priorities were determined after each option's importance concerning each indicator (altitude, slope, land-use compatibility, land capability, access to roads, distance from gas pipelines, and distance from power lines). In this step, the relative weights of each index were combined with the relative weights of each of the options obtained by using the Raster Calculator function and averaged from them. The resulting number actually demonstrates which area has the highest priority in creating the intended activities. In fact, the higher the score, the higher the priority. Based on this, the status of Tonekabon City activities is as follows:

### 3.3.1. Residential Activities

EIPs of Tonekabon City for establishing residential centers are that from 2,645,770,990 square meters of this area, 38,773,342 m<sup>2</sup> are in a completely unsuitable condition, 2,873,254 m<sup>2</sup> in a relatively unsuitable status, 622,045,411 m<sup>2</sup> in a moderate position, almost 467,415,693 m<sup>2</sup> in relatively suitable terms, and 1,338,663,290 m<sup>2</sup> in a completely suitable situation in order to create residential activities. Figure 14 shows the final valuation of EIPs for the establishment of residential centers.

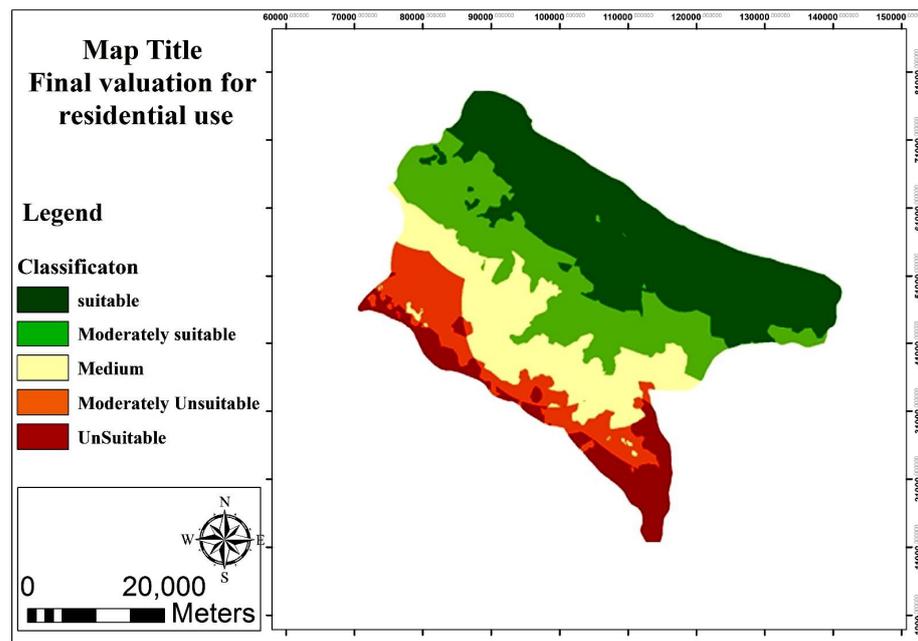


Figure 14. Final valuation for the development of residential activities.

### 3.3.2. Tourism Activities

The second activity is tourism used in this paper. The situation of EIPs of Tonekabon City for the formation of tourism centers is that 4,930,698 m<sup>2</sup> is in a completely unsuitable setting, 281,813,198 m<sup>2</sup> in a relatively unsuitable location, 853,983,198 m<sup>2</sup> in a moderate size, 1,134,995,696 m<sup>2</sup> in a relative suitable spot, and 370,048,200 m<sup>2</sup> in a completely suitable position. Figure 15 indicates the final valuation of EIPs for tourism.

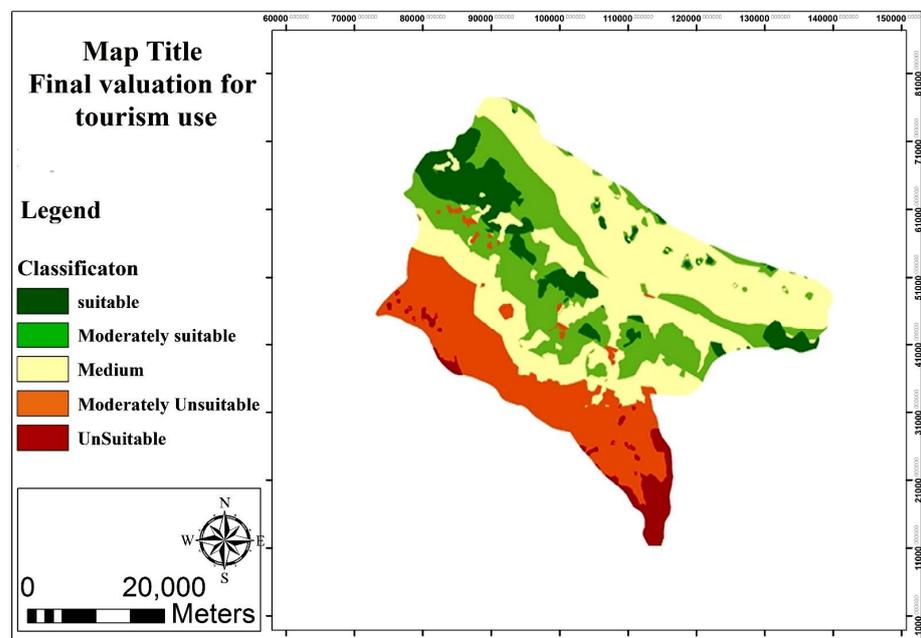


Figure 15. Final valuation for the development of tourism activities.

### 3.3.3. Agricultural Activity

The third activity is agriculture in this research. The status of EIPs of Tonekabon City for setting up the centers of agricultural activities is that about 100,955,300 m<sup>2</sup> is in a completely unsuitable position, 300,140,471 m<sup>2</sup> in a moderately unsuitable condi-

tion, 1,310,290,742 m<sup>2</sup> in a moderate status, 659,500,903 m<sup>2</sup> in a moderately setting, and 274,883,574 m<sup>2</sup> in a whole situation. Figure 16 indicates the final assessment of EIPs for agricultural activities.

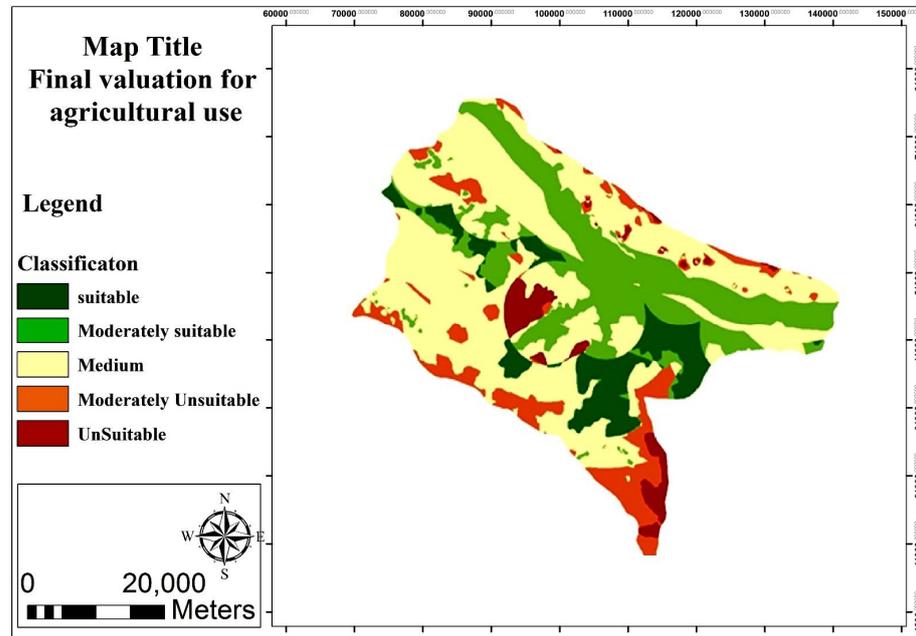


Figure 16. Final valuation for the development of agricultural activities.

### 3.3.4. Forestry activity

The fourth activity is forestry in this article. EIPs of Tonekabon for forestry use is that nearly 4,930,690 m<sup>2</sup> is in a completely unsuitable location, 281,813,200 m<sup>2</sup> in a moderately unsuitable position, 370,048,202 m<sup>2</sup> in a moderate situation, 1,134,995,700 m<sup>2</sup> in a moderately suitable setting, and 853,983,198 m<sup>2</sup> in a completely suitable condition. Figure 17 indicates the final evaluation of EIPs of Tonekabon City for forestry activities.

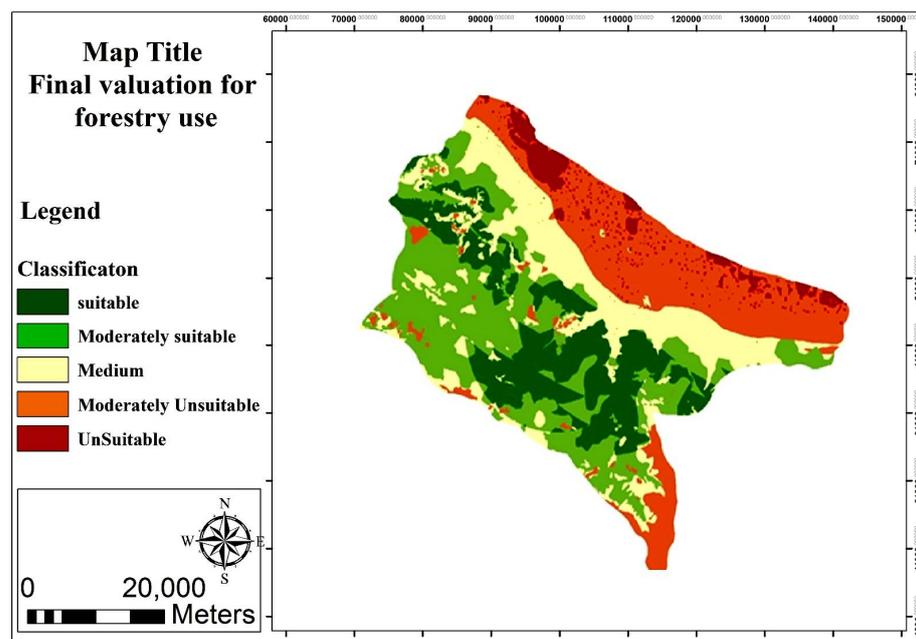


Figure 17. Final valuation for the development of forestry activities.

#### 4. Discussion

This study used ecological viability parameters to plan and develop land uses and activities. According to the conditions of the study area, it seems that factors such as slope, elevation, and land capability in assessing the area's potential had the greatest impact on different uses because the variety of these factors in the region is very high. For example, the slope of the area varies from 0 to more than 65%. Therefore, in the region, a slope of less than 15% is possible for agricultural and residential activities, and higher slopes are possible for forestry and tourism activities.

In general, the factors are widely influential in assessing land potential in a region where they have the most immense diversity in the region and put the most constraints.

In the present study, the status of EIPs for four activities is presented in five classes. Classes 1 and 2 (suitable and moderately suitable) represent lands with high EIPs. Class 3 (medium) indicates lands with medium EIPs, and classes 4 and 5 (moderately unsuitable and unsuitable) show lands with low and very weak EIPs.

##### 4.1. Agricultural Activity

The results of studies show that the suitable slope for agricultural activities is less than 15%. All the northern parts and a significant part of the central parts of the city have suitable slopes for agricultural activities.

In the land-use compatibility index, most parts of the city are compatible with agricultural activities. Limited parts in the north (coastal part) are incompatible for development due to the high density of housing and population.

In the land capability index, areas with low elevation are considered suitable for the development of agricultural activities. Therefore, a large part of the southern parts is not suitable for the development of this activity due to the high elevation. The coastal part is also unsuitable for developing agricultural activities due to the characteristics of the land's hydrology, salinity, and sandiness. The suitable parts of the land for the development of agricultural activity are the central parts of the city because they are in suitable condition in terms of underground water level, topographic and geological features.

The next indicator of ecological viability is access to roads. Roads are considered vital arteries and the most important infrastructure factor for agricultural activities. The northern areas of Tonekaban have a more suitable situation for the development of agricultural activities in terms of access to roads because access to suitable roads, in addition to reducing transportation costs and travel time, plays an important role in the economic development of agriculture. As the distance from the roads increases and access becomes more difficult, the development becomes less suitable for agricultural activities. The southern areas of Tonekaban lack suitable land for agricultural activities due to the lack of proper road access.

In the indicators of distance from electricity and gas lines, optimal places for agricultural activities are places that are far from these lines. Therefore, the optimal places for the development of agricultural activity are the central and southern parts, considering the establishment of gas channels and power lines in the northern parts. The final evaluation of all the indicators for agricultural activity shows that the northern (far from the coastal zone) and central parts have been evaluated as very suitable areas for agricultural activity.

When it comes to agricultural-pasture activities, classes 1 and 2 can be considered suitable for the main agricultural activities, and classes 4 and 5 can be regarded as suitable for pasture activities. The findings of this study clarify that areas with agricultural potential 1 and 2 are mainly located on slopes with low percentages and fertile soils and short distances from residential centers. Table 6 indicates the area and percentage of ecological potential of lands for agricultural activities. In this paper, 35% of the study area has a high potential for agriculture and pasture activities, 49.5% is on the medium level, and less than 15% is unsuitable for agriculture and pasture. The correct interpretation of the results and their comparison with the region's conditions reveal that in relatively wide areas with the potential of grades 1 and 2 for agriculture, the existing conditions are favorable for agriculture and this activity should be developed and strengthened. In the region with

grade 3 (medium), conditions for gardening and farming can be suitable for other sectors and ancillary activities of agriculture, such as conversion industries and forage cultivation.

**Table 6.** Area and percentage of land classification to assess the ecological potential.

Activity		Suitable	Moderately Suitable	Medium	Moderately Unsuitable	Unsuitable
Agricultural	Area (square meters)	274,883,574	659,500,903	1,310,290,742	300,140,471	100,955,300
	Percentage	10.39	24.93	49.52	11.34	3.82
Forestry	Area (square meters)	853,983,198	1,134,995,700	370,048,202	281,813,200	4,930,690
	Percentage	32.28	42.9	13.98	10.65	0.18
Tourism	Area (square meters)	274,883,574	659,500,903	1,310,290,742	300,140,471	100,955,300
	Percentage	10.39	24.93	49.52	11.34	3.82
Residential	Area (square meters)	1,338,663,290	467,415,693	622,045,411	2,873,254	38,773,342
	Percentage	54.2	18.92	25.18	0.12	1.57

#### 4.2. Forestry Activity

The slope plays an important role in evaluating the ecological potential of the area for forestry. The inappropriate slope of some parts (especially the southern areas) leads to restrictions in forestry-related activities, including working with different machines, limiting the presence in the forest area, harsh climatic and environmental conditions, and the like. Therefore, lower slopes are more favorable for forestry (although some sources have not considered a limit for the slope for forestry activity). The northern and central parts have been evaluated as very suitable for developing forestry activities due to the slope of the region.

In the land-use compatibility index, most parts of the city are compatible with forestry activities. Limited parts in the north (coastal area) are incompatible for development due to the high density of housing and population because the development of land uses related to human and population activities are opposed to forestry activities.

In the land capability index, high forested mountains are prioritized for the development of forestry activities. Except for the northern parts of the region (due to lack of forest cover), other parts of the region are considered suitable for the development of forestry activities due to suitable forest cover. The northern region, especially the region's coastal areas, is unsuitable for the development of forestry activities due to the lack of forest cover and the land's hydrology, salinity, and sandy nature.

In the Road accessibility index (RAI), the parts located near the main roads are not evaluated as suitable for the development of forestry activities because the destruction of forest lands accompanies the construction of the crossing and reconstruction of roads and streets. Therefore, the central and southern parts of the region are suitable for the development of forestry activities due to the distance from the main road networks. In indicators of distance from electricity and gas lines, such as agricultural activities, optimal places for forestry activities are places that are far from these lines. Therefore, a significant part of the optimal places for the development of forestry activities is the central and southern parts.

According to the final valuation, the central and southern parts are suitable for forestry activities. One of the most important reasons for this is the high density of forest lands in these parts and the high share of land-use compatibility indicators and land capability for the development of this activity.

The outcomes of potential ecological assessment for forestry use demonstrate that the second class (moderately suitable) has the highest level with an area of 42.9% of the total area. In the second place is the first class (suitable), where 32.28% of the lands are situated

in this part, and this shows that more than 70% of the lands have a high ecological potential for forestry and less than 11% have low ecological potential (Table 6).

#### 4.3. Tourism

The suitable slope for tourism activity was considered to be less than 25%. There is a possibility of tourism activities on slopes of more than 25%, but it is not considered due to geological risks and lower economic efficiency. The northern and central parts are suitable for the development of tourism activities due to the slope of the region.

Compatible areas for the development of tourism activities are located in limited parts of the north of the region, which are the coastal part. The reason for the limitation of the ranges in the compatibility index is that; the development of tourism activities leads to a huge demand for recreational land use and causes changes in the land use pattern.

In the land capability index, forested mountains are suitable for developing tourism activities. Most parts of the region, especially the central and southern parts, are suitable for developing tourism activities due to the suitable forest cover.

In the Road accessibility index (RAI), the parts that are located near the main roads are prioritized for the development of tourism activities. Therefore, the northern parts have been evaluated as suitable centers for the development of tourism activities due to the access to the main road networks. In the indicators of distance from electricity and gas lines, the optimal places for tourism activities are the places that are close to these lines. Therefore, the northern and central parts are suitable for developing this activity. As it was determined from the final evaluation, the central parts and parts of the north (especially the coastal part) have been evaluated as suitable for tourism activities. One of the most important reasons for this is the coast in the north of the region and the density of forest land, low elevation, suitable slope, and access to infrastructure in these parts.

On the other hand, in Table 6, less than 15% of the lands are unsuitable for tourist activities, and more than 70% are in the first, second, and third classes (suitable, moderately suitable, and medium) for locating tourism activities.

#### 4.4. Residential Activity

The slope plays a vital role in choosing the right and optimal place to establish settlements and service networks and reduce natural disasters. Establishing settlements on high slopes should always be considered a limiting factor in providing services and other activities. As the slope increases, the cost of construction and deployment of equipment and facilities increases greatly. Therefore, the appropriate slope for settlement activity was considered less than 15%. The northern area of Tonekabon is the best place for the development of settlements. Currently, the highest population density is scattered in the northern part and on the beach strip.

The central and southern parts of Tonekabon have been evaluated because of unsuitable places due to the increase in the height of settlements, because in high lands, in addition to the problems that exist in terms of high economic costs, transportation, etc., for settlements and activity, in terms of climate also causes problems, because the high reduction in the atmosphere and as a result, the reduction in oxygen that occurs at high elevations is dangerous for life and permanent settlement. Ease of access to urban services, comfort, efficiency, utility, health, and safety standards have been the essential principle in the compatibility criteria for the development of settlement activities. Distance from polluting uses (industrial, transportation land uses, etc.) and proximity to complementary land uses are sometimes considered among the most important compatibility criteria due to the nature of the residential activity because they increase accessibility and efficiency. According to the above description, the northern areas (half-beach) are suitable for development due to the presence of complementary uses and access to urban services and facilities.

In the land capability index, flood plains and areas with low elevation are suitable for the development of settlement activity. According to the features of land capability, the northern parts and the beach strip have the most suitable lands for developing resi-

dential activities. With the increase in altitude and change in topographical conditions, change in texture and type of soil and rock, the conditions are limited for the development of settlement activities, so the southern parts are very unsuitable for developing these activities.

In the road accessibility index, such as tourism and agricultural activities, proximity to the main roads is suitable for the development of residential activities. Therefore, the northern and central parts are very suitable for developing these activities. In the indicators of distance from electricity and gas lines, the optimal places for residential activities are sometimes close to these lines. Therefore, the northern and central parts are suitable for the development of this activity. The final valuation for residential activities shows that; the northern areas have more suitable lands than the southern areas. One of the most important reasons that can be mentioned is the topographical factors and access to roads and services.

The assessment of the ecological potential for residential use proves that more than 54% of the lands are in a very suitable condition for residential use (Table 6). As can be seen, more than 73% were assessed as suitable and moderately suitable for residential activities.

## 5. Conclusions

Assessment of ecosystem viability is performed according to the uniqueness of each region's ecological characteristics based on that region's criteria and regulations. According to the characteristics of Tonekabon City, the indicators of topography (slope, aspect, elevation), land-use compatibility, land capability (hydrology, geomorphology), road access, distance from electricity transmission lines, distance from gas transmission lines were used to evaluate the ecological viability.

According to the results of the surveys, the southern part of Tonekabon City is surrounded by high elevations and mountains. The southern areas lack development capabilities for some activities. Among the four activities of the current research, only the development of forestry activities is possible in this part. Therefore, activities such as residential, agriculture, and even tourism are facing restrictions for development due to the inappropriate elevation and slope and the presence of thick and dense vegetation and trees in the southern areas, but the compatibility of land uses and land capability is more important for the development of forestry activities. Therefore, areas with a high tree and forest cover density have a more suitable ecological capacity for development.

In the studied area, the most crucial land limitation factors for agricultural development are slope and erosion, depth, texture, and soil salinity. The high slope causes erosion in agricultural areas (rainfed and irrigated), which causes many problems when compared to low slope land. However, access to infrastructures such as roads and communication networks plays an important role in the development of this activity. Therefore, the northern (far from the coast) and central parts of Tonekabon are suitable for agricultural activities. The southern parts of the city do not have suitable lands for the development of agricultural activities due to the steep slope.

Nurmiaty and Baja (2013) researched to evaluate land suitability based on spatial analysis for the development of agricultural products (maize) in Marus, South Sulawesi, Indonesia and concluded that the most important limiting factor for agricultural development in the region is the steep slope. Therefore, it is consistent with the results of the present research.

In the northern parts of Tonekabon City, which is in the form of plains, it has almost the ability and potential for all activities except forestry. Meanwhile, tourism and settlement activities sometimes have more ideal conditions for development due to suitable topographical conditions and access to communication and infrastructure networks. According to the results of the research, the development of tourism and residential activities in the southern parts of Tonekabon has a pattern that contradicts the principles of sustainable development.

In fact, the development of tourism and residential activities is in conflict with the approach of sustainable development with the destruction of land resources and productive lands (agricultural and orchards), while land resources are considered to be the main

ecological resources of any tourist destination, destruction, and unprincipled changes mean the destruction of tourism resources. Rocky and uneven lands, steep slopes, weak communication and infrastructure networks, and the lack of establishment of complementary uses in the southern areas of Tonekabon are the reasons for the limitation of development for settlement and tourism activities.

Therefore, the northern and central zones have high power and potential for establishing settlement and tourism activities. It is important to note that the simultaneous implementation of several activities in one place is not possible in most cases to maintain the stability of the area, and the best activity or use must be chosen for it among the options of available activities.

The results of this study, such as the other ecological livability researches ([21,25,46] Li et al., 2021; Zhao et al., 2022). Take the impact of ecological aspects, environment, and ecosystem into consideration. The outcomes of the above studies emphasize that in addition to ecological indicators, the level of development of public services and urban infrastructure (physical-social indicators) have consequential effects on ecological livability, which is consistent with the result of the current paper. The present study can be a useful and reliable reference for livability analysis with a sustainable development approach because the focus of the study is on understanding the strengths and limitations of the study area. Consequently, the evaluation model of the present study can be the basis of work for future studies to provide the basic and rational groundwork for creating a scientific, accurate, and comprehensive system in the future.

#### *Recommendations*

1. The existence of different organizations for each of the activities is one of the problems in the development of activities, which causes many problems. Organizations responsible for the settlement include the Municipality, The Department of Roads and Urban Development, Gas Company, Electricity Company, and Water Company. The organization accountable for agriculture is Agriculture Jihad. The organization responsible for tourism is the Department of Cultural Heritage and Tourism. The responsibility for forestry activities is also the responsibility of the Natural Resources and Watershed Management Organization. All these organizations evaluate the problems according to their facilities and work duties and lack a comprehensive vision. In addition, there is no meaningful relationship between them, and there is no proper interaction between them in urban problems. For this reason, many costs are brought into the city system every year due to the inconsistency of the organizations. Therefore, integrated urban management is an essential prerequisite for the development of activities. Integration in system management, in addition to the effective interaction of organizations, facilitates management by addressing all elements and saves time and efficiency.

2. It is necessary not to use the resources indiscriminately, not to destroy the land, and to pay attention to the criteria of sustainable development considering the high ecological potential of the region for the development of activities;

3. As it was determined, the northern and central areas are suitable for developing tourism and residential and agricultural activities. Therefore, developing infrastructure (hotels, parks, restaurants, etc.) and communication networks in the northern and central areas is necessary;

4. Attracting investment is one of the most critical factors in the development of activities. Various companies and organizations can be encouraged to invest by introducing the potential of the region through creating websites, holding conferences, printing books and brochures, and making films.

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